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Determination of the Type of Heart Syndrome in Traditional Chinese Medicine with the Bayesian Network Method

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Abstract - The determination of a disease syndrome in the Traditional Chinese Medicine (TCM) is difficult to determine. It requires a lot of experience in observing patient's symptoms that appear in disease syndrome and their disease syndrome history. Symptoms that appear in one disease syndrome are varied and can also appear in other disease syndromes. This research limits the determination of the type of syndrome only in the heart organ. The purpose of this study is to determine the type of heart syndrome in TCM by using Bayesian Networks. Bayesian Networks is used because it has the advantage of adapting expert knowledge toward the preferences of symptoms that arise at a type of heart syndrome. The expert's preference is in the weights that act as prior probabilities that are used as the basis for calculations on the Bayesian Networks. The results showed that the Bayesian Networks could be used to determine the type of heart syndrome well. The trials on seven patients yield the same diagnosis between the doctor's diagnosis and the Bayesian Networks calculation.

Keywords – Bayesian Network, Bayes Naïve, Weight preference, TCM, Knowledge Base

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I. INTRODUCTION

The development of eastern medical science, better known as Traditional Chinese Medicine (TCM), was also has developed in Indonesia as one of the widely used treatments by Indonesian people. The kind of TCM treatment includes acupuncture, herbs, acupressure, tuina. In studying TCM, there are some problems in determining a syndrome of disease because physicians and TCM practitioners have to identify the symptoms that arise from the patients. In TCM, to determine the syndrome of a disease, there are many difficulties for someone to determine the syndrome. It takes a lot of experience in diagnosing to identify a patient's disease syndrome. This identification will take a long time. Therefore, it needs a method that can help in determining disease syndrome. One way to overcome this problem is through the Bayesian Network, which can help physicians and TCM practitioners identify a syndrome of disease. Bayesian Network is a graphical model that encodes probabilistic relationships between each variable. Bayesian Networks can show

the probability of a relationship between related or unrelated events [1].

Nowadays, Bayesian Network has been widely used in solving problems faced by humans. In the modeling area, such as environments ecosystems, Bayesian Network can help determine a suitable model [2], and Bayesian Network also capable to model the risk of Coronary artery disease [3]. In the visual area, Bayesian Networks have been used to detect the visual quality of textiles [4] and to detect errors in blood laboratory results [5]. In the health area, Bayesian Network is used to diagnose influenza in patients [6], to determine the risk of re-intervention after endovascular aortic aneurysm repair [7] and also capable of detecting Breast Cancer Screening for patients [8] and [9]. This study aims to determine a disease syndrome in the heart organ in TCM by using the Bayesian Network. In determining the type of heart organ syndrome, each syndrome has quite a lot of symptoms, so it needs the right method to help determine the type of syndrome. Bayesian Network can help determine the type of syndrome by using the

expert's preference weights for symptoms that appear in heart syndrome.

II. RESEARCH METHOD

This research was conducted consisting of 8 stages, as shown in Fig.1 a block diagram of the study, namely,

1. Identify types and symptoms in heart syndrome.
2. Build a Bayesian Network based on the relationship of symptoms to the type of heart syndrome.
3. Determine the value of the prior probability of the expert.
4. Build a Conditional Probability Table (CPT).
5. Determine Joint Probability Distribution (JPD).
6. Calculate the Posterior Probability.
7. Calculate Probabilistic Inference.
8. Select a type of heart syndrome.

The first stage is to identify symptoms in heart syndrome through a literature study using heart symptoms that are in reference [10]. Information from the literature obtained types of heart syndrome and the accompanying symptoms. Types of heart syndrome include,

1. Heart qi deficiency.
2. Heart blood deficiency.
3. Hyperactivity of the heart fire.
4. Phlegm misting the heart.
5. Stagnation of heart blood.

The second stage is to build a Bayesian Network based on the relationship of symptoms to the type of heart syndrome. Each type of heart syndrome has its symptoms, and some symptoms appear in other types of heart syndrome. Fig.2 shows the Bayesian Network of heart syndrome.

The third phase is to determine the value of the prior probability of the expert, then retrieve data to determine the weight of symptoms that appear in each type of heart syndrome. The expert was a physician who was also a TCM expert that served at Lembaga Penelitian dan Pengembangan Pelayanan Akupunktur (LP3A) in Surabaya. This data is taken, referring to research [11].

The fourth phase is to build the Conditional Probability Table (CPT). After knowing the prior probability, the next step is to determine the conditional probability between the types of heart syndrome and their symptoms. The Conditional Probability value is obtained based on the estimated parameters obtained in the previous step. Conditional Probability is denoted $P(B|A)$, which means the probability of a condition A if it is known that condition B has occurred. This theorem is used to calculate the probability of a data set entering a particular class based on existing data inferences.

Bayes's theorem is an approach to uncertainty as measured by probability in (1) that is to say [12],

$$P(A|B) = \frac{P(A \cap B)}{P(B)} = \frac{P(B|A)P(A)}{P(B)} \quad (1)$$

Where:

$P(A|B)$: posterior probability, i.e., the opportunity of A event happens after B event happens.

$P(A \cap B)$: the opportunity of B event and A event happen to coincide.

$P(B|A)$: the likelihood, i.e., the opportunity of B event happens after the opportunity of A event happens.

$P(A)$: the prior, the opportunity of A event.

$P(B)$: the opportunity of B event.

The fifth stage is to determine the Joint Probability Distribution (JPD). Like CPT, the joint probability distribution of variables A and B is a table that contains the probabilities for each value A and B that can occur. In this case, variable A refers to patients suffering from an illness in a type of heart syndrome, and variable B refers to having a positive symptom of heart syndrome. To get the joint probability distribution by calculating the product of the conditional probability and prior probability, as shown in (2), that is to say [12],

$$P(A \cap B) = P(A) P(B|A) \quad (2)$$

Where:

$P(A \cap B)$: joint probability distribution.

$P(A)$: prior probability.

$P(B|A)$: the conditional probability.

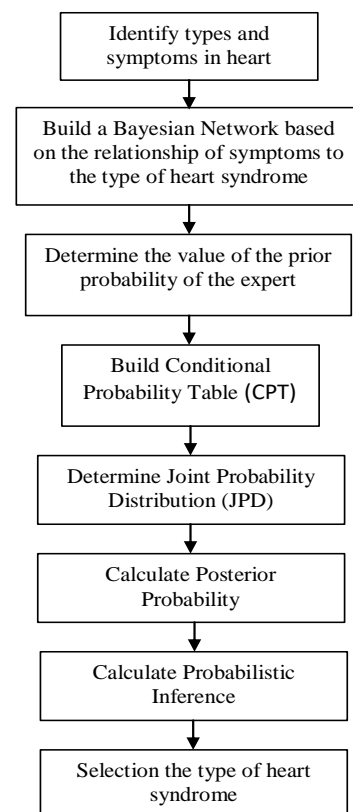


Fig. 1. Research Block Diagram

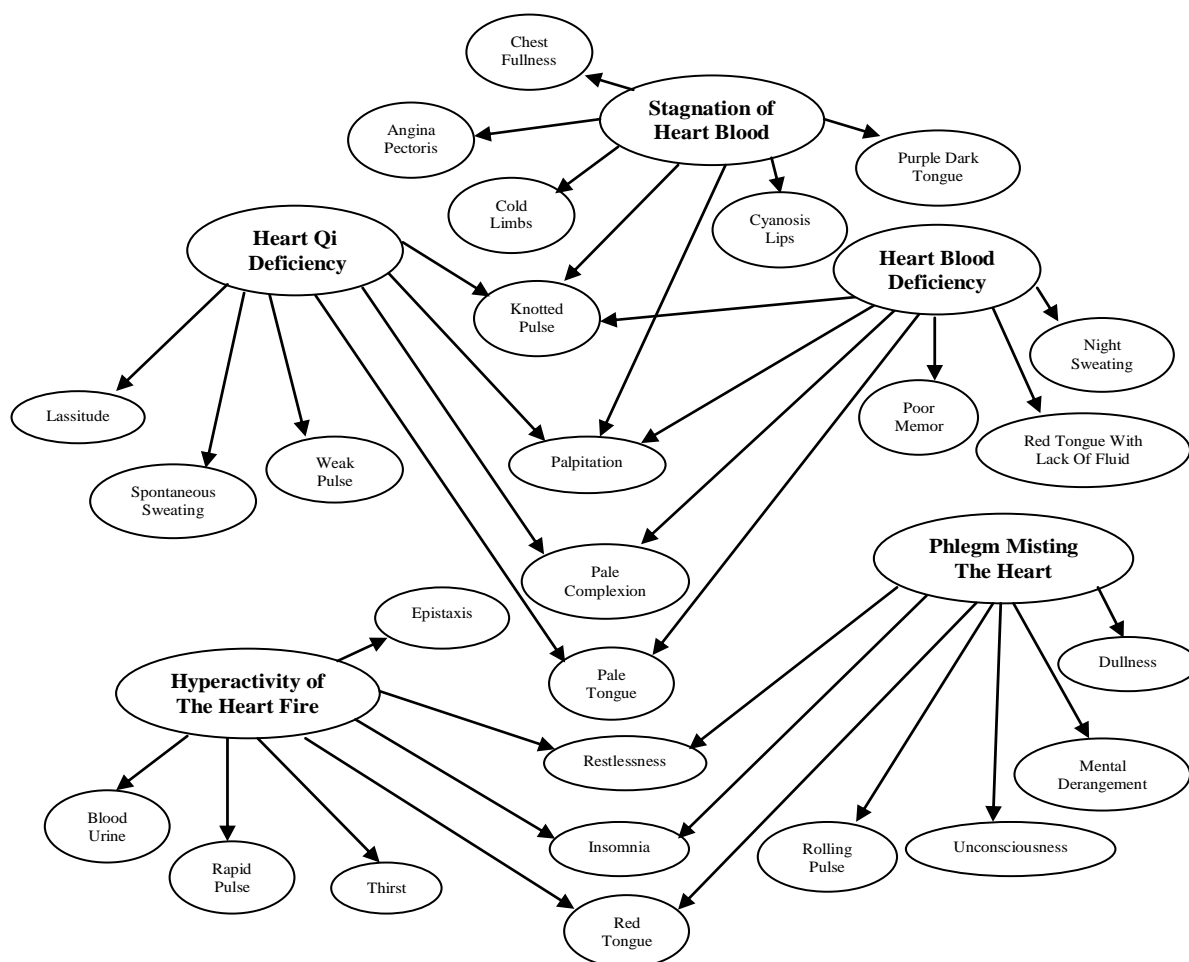


Fig. 2. The Heart Syndrome Bayesian Network

The sixth stage is to Calculate Posterior Probability, it can be calculated from the results of the Joint Probability Distribution (JPD) that has been obtained, and then this value is used to calculate the probability of occurrence of a symptom [13]. At the seventh stage is to calculate the Probabilistic Inference. at this stage, a probabilistic inference is made based on the presence or absence of symptoms. After the rule table and the posterior value of each symptom are known, the probability of each disease's symptoms from the Bayesian Network structure has been calculated. This probability calculation process is intended to determine the estimated value of the symptoms suffered by the patient so that it can find out how much the probability that the patient has a disease. Next, in the last stage or stage 8, is to select the type of heart syndrome. This stage is done by determining the highest value of calculation; the highest value indicates the type of heart disease syndrome.

III. RESULT

This study used the Bayesian Networks method to determine the type of heart syndrome. The research results from stages 1 through 3 are to identify the symptoms that accompany each type of syndrome. Table 1 shows the five types of heart syndromes and

their symptoms. Furthermore, the weight is obtained from the preferences of a TCM expert, namely a doctor on duty at LP3AI in Surabaya. This data refers to research [11]. Furthermore, the weight of expert preference becomes the prior probability value of the symptoms of the syndrome.

Table 1. Type of Heart Syndrome, Symptoms and Weight

Type of Heart Syndrome	Symptoms	Weight
Heart Qi Deficiency	Pale Complexion	0.7
	Palpitation	0.8
	Spontaneous Sweating	0.8
	Lassitude Worse On Exertion	0.8
	Pale Tongue With White Coating	0.8
	Weak and Forceless Pulse	0.8
	Knotted and Intermittent Pulse	0.7
Heart Blood Deficiency	Pale Complexion	0.8
	Palpitation	0.8
	Poor Memory	0.7
	Night Sweating	0.8
	Pale Tongue	0.8

Type of Heart Syndrome	Symptoms	Weight
Hyperactivity of The Heart Fire	Red Tongue With Lack Of Fluid	0.3
	Knotted And Intermittent Pulse	0.7
	Restlessness	0.8
	Insomnia	0.8
	Thirst	0.8
	Epistaxis	0.8
	Bloody Urine	0.7
Phlegm Misting The Heart	Red Tongue	0.8
	Rapid Pulse	0.8
	Restlessness	0.8
	Insomnia	0.8
	Mental Derangement	0.8
	Unconsciousness	0.8
	Dullness	0.8
Stagnation of Heart Blood	Red Tongue With Sticky Coating	0.8
	A String-Taut And Rolling Pulse	0.8
	Palpitation	0.7
	Chest Fullness	0.8
	Angina Pectoris Referring To The Shoulder And Arm	0.8
	Cold Limbs	0.8
	Cyanosis Of The Lips	0.8
	A Purplish Dark Tongue With Purplish	0.8
	Knotted And Intermittent Pulse	0.7

In stage 4 is to determine the value of conditional probability between each type of syndrome with its symptoms. The positive-present value is based on the weight of the expert, and the remaining column is the result of subtraction from the next column, for example, value for weight value of 0.3. Then the positive-absent value is $1 - 0.3 = 0.7$. Table 2 shows the calculation of the Conditional Probability that represents symptom weight value from experts for heart blood deficiency syndrome.

Table 2. Conditional Probability of Heart Blood Deficiency

Pale Complexion (Weight= 0.8)	Heart Blood Deficiency	
	Present	Absent
Positive	0.8	0.2
Negative	0.2	0.8
Bloody Urine (Weight = 0.7)	Heart Blood Deficiency	
	Present	Absent
Positive	0.7	0.3
Negative	0.3	0.7
Red Tongue With Lack of Fluid (Weight= 0.3)	Heart Blood Deficiency	
	Present	Absent
Positive	0.3	0.7
Negative	0.7	0.3

The fifth stage is to determine the value of the joint probability for each value representing the symptoms that can occur. To get a joint probability distribution, that is by calculating it by multiplying the conditional probability and prior probability. Table 3 shows an example of the calculation of the Joint Probability of Heart Blood Deficiency.

Table 3. Joint Probability of Heart Blood Deficiency

Pale Complexion (Weight= 0.8)	Heart Blood Deficiency	
	Present	Absent
Positive	$0.8 \times 0.8 = 0.64$	$0.2 \times 0.2 = 0.4$
Negative	$0.8 \times 0.2 = 0.16$	$0.2 \times 0.8 = 0.16$
Bloody Urine (Weight = 0.7)	Heart Blood Deficiency	
	Present	Absent
Positive	$0.7 \times 0.7 = 0.49$	$0.3 \times 0.3 = 0.9$
Negative	$0.7 \times 0.3 = 0.21$	$0.3 \times 0.7 = 0.21$
Red Tongue With Lack of Fluid (Weight= 0.3)	Heart Blood Deficiency	
	Present	Absent
Positive	$0.3 \times 0.3 = 0.9$	$0.7 \times 0.7 = 0.49$
Negative	$0.3 \times 0.7 = 0.21$	$0.7 \times 0.3 = 0.21$

The sixth step is to determine the presence or absence of symptoms that the patient has by calculating the probability of symptoms of each syndrome of the Bayesian Network structure that has been made. This probability calculation process is intended to determine the estimated value of the symptoms suffered by the patient so that we can find out how much the probability that the patient has a syndrome. The posterior probability calculation formula applies to all weight values in each symptom of the syndrome. For example, for expert weights 0.8 based on the Join Probability Distribution (JPD) table above are as follows. The calculation for symptoms of the syndrome present in patients:

$$P(A|B) = \frac{P(A \cap B)}{P(B)} = \frac{P(A)P(B|A)}{P(B|A)P(A) + P(B|\bar{A})P(\bar{A})}$$

$$P(A|B) = \frac{0.64}{0.64+0.4} = \frac{0.64}{1.04} = 0.615385$$

The calculation for symptoms of the syndrome absent in patients:

$$P(A|B) = \frac{P(A \cap B)}{P(B)} = \frac{P(A)P(B|A)}{P(B|A)P(A) + P(B|\bar{A})P(\bar{A})}$$

$$P(A|B) = \frac{0.16}{0.16+0.16} = \frac{0.16}{0.32} = 0.5$$

At stage 7 is the probabilistic inference process is based on the presence or absence of symptoms owned by the patient and adapted to the structure of the Bayesian network of each syndrome. The probabilistic inference process is carried out by calculating the multiplication between the present's weight and the absent weight in each syndrome. The result of this multiplication is the weight value for the related syndrome. The syndrome with the highest

weight value is the diagnosis of the syndrome the patient has, which is the conclusion of checking the diagnosis of the syndrome.

For example, symptoms that appear in patients such as palpitation, insomnia, and thirst, then the weight of the symptom is considered as a present weight value. The rest of the symptoms do not appear in the patient, then it is considered as an absent weight value. The result of multiplying all the weight values will be the total weight value that will be compared with the value of other syndromes experienced by the patient. The process for calculating the syndrome probability data is as follows:

P (Heart Qi Deficiency| Pale Complexion: No, Palpitation: Yes, Spontaneous Sweating: No, Lassitude Worse on Exertion: No, Pale Tongue with White Coating: No, Weak and Forceless Pulse: No, Knotted and Intermittent Pulse: No)

$$= 0.5 \times 0.615385 \times 0.5 \times 0.5 \times 0.5 \times 0.5 \times 0.5$$

$$= \mathbf{0.009615}$$

P (Heart Blood Deficiency| Pale Complexion: No, Palpitation: Yes, Poor Memory: No, Night Sweating: No, Pale Tongue: No, Red Tongue With Lack Of Fluid: No, Knotted And Intermittent Pulse: No)

$$= 0.5 \times 0.615385 \times 0.5 \times 0.5 \times 0.5 \times 0.5 \times 0.5$$

$$= \mathbf{0.009615}$$

P (Hyperactivity of The Heart Fire| Restlessness: No, Insomnia: Yes, Thirst: Yes, Epistaxis: No, Bloody Urine: No, Red Tongue: No, Rapid Pulse: No)

$$= 0.5 \times 0.615385 \times 0.615385 \times 0.5 \times 0.5 \times 0.5 \times 0.5$$

$$= \mathbf{0.011834}$$

P (Phlegm Misting The Heart| Restlessness: No, Insomnia: Yes, Mental Derangement: No, Unconsciousness: No, Dullness: No, Red Tongue With Sticky Coating: No, A String-Taut and Rolling Pulse: No)

$$= 0.5 \times 0.615385 \times 0.5 \times 0.5 \times 0.5 \times 0.5 \times 0.5$$

$$= \mathbf{0.009615}$$

P (Stagnation of Heart Blood| Palpitation: Yes, Chest Fullness: No, Angina Pectoris Referring to The Shoulder and Arm: No, Cold Limbs: No, Cyanosis Of The Lips: No, A Purplish Dark Tongue With Purplish: No, Knotted And Intermittent Pulse: No)

$$= 0.615385 \times 0.5 \times 0.5 \times 0.5 \times 0.5 \times 0.5 \times 0.5$$

$$= \mathbf{0.009615}$$

Stage 8 determines the type of heart syndrome by selecting the greatest probability calculation result. In the example above, the greatest probability is in the hyperactivity syndrome of the heart fire that is equal to **0.011834**. Furthermore, a trial was carried out toward seven patients' data that had been diagnosed manually by a doctor and the results of a diagnosis of heart syndrome using the Bayesian Network Method. Table 4 shows the results of probability calculations

that show the same results as a doctor's diagnosis manually.

Table 4. Comparison of Diagnosing Doctor and Bayesian Network Calculation Results

ID Patient	Symptoms that Appear	Physician's Diagnose	BN' Diagnose
1	<ul style="list-style-type: none"> - palpitation - a pale tongue with the moist coating - weak forceless pulse, - a pale tongue 	Heart Qi Deficiency	Heart Qi Deficiency (0.01456534)
			Heart Blood Deficiency (0.01183433) Hyperactivity Of The Heart Fire (0.0078125) Phlegm Misting The Heart (0.0078125) Stagnation Of Heart Blood (0.00550809)
5	<ul style="list-style-type: none"> - pale complexion - weak forceless pulse, - a pale tongue with the moist coating - angina pectoris referring to the shoulder and arm, 	Heart Qi Deficiency	Heart Qi Deficiency (0.01456534)
			Heart Blood Deficiency (0.00961539) Hyperactivity Of The Heart Fire (0.0078125) Phlegm Misting The Heart (0.0078125) Stagnation Of Heart Blood (0.00961539)
18	<ul style="list-style-type: none"> - pale complexion, - palpitation - spontaneous sweating, - weak forceless pulse, - general lassitude, - a pale tongue with moist coating, 	Heart Qi Deficiency	Heart Qi Deficiency (0.015555567)
			Heart Blood Deficiency (0.014565344) Hyperactivity Of The Heart Fire (0.0078125) Phlegm Misting The Heart (0.0078125) Stagnation Of Heart Blood (0.005508094)
35	<ul style="list-style-type: none"> - palpitation, - insomnia, - red tongue with a sticky coating, - mental derangement 	Phlegm Misting The Heart	Heart Qi Deficiency (0.009615) Heart Blood Deficiency (0.009615) Hyperactivity Of The Heart Fire (0.009615)
			Phlegm Misting The Heart (0.014565) Stagnation Of

ID Patient	Symptoms that Appear	Physician's Diagnose	BN' Diagnose
45	- palpitation, - insomnia, - thirst,	Hyperactivity Of The Heart Fire	Heart Blood (0.005508)
			Heart Qi Deficiency (0.009615)
			Heart Blood Deficiency (0.009615)
			Hyperactivity Of The Heart Fire (0.011834)
			Phlegm Misting The Heart (0.009615)
56	- restlessness, - thirst, - insomnia,	Hyperactivity Of The Heart Fire	Stagnation Of Heart Blood (0.005508)
			Heart Qi Deficiency (0.007813)
			Heart Blood Deficiency (0.007813)
			Hyperactivity Of The Heart Fire (0.014565)
			Phlegm Misting The Heart (0.011834)
88	- spontaneous sweating, - lassitude worse on exertion - red tongue with lack of fluid, - rapid pulse, - thirst, - insomnia	Hyperactivity Of The Heart Fire	Stagnation Of Heart Blood (0.007813)
			Heart Qi Deficiency (0.0118343)
			Heart Blood Deficiency (0.0024246)
			Hyperactivity Of The Heart Fire (0.0179266)
			Phlegm Misting The Heart (0.0118343)
			Stagnation Of Heart Blood (0.0078125)

IV. DISCUSSION

One of the problems in TCM is to determine what kind of type of heart syndrome suffered by the patients. If this diagnosis has been made conventionally, it will require a long time and automatically requires a lot of costs as well. Someone who is just learning TCM must find a patient to study the symptoms that appear and then determine what syndrome is causing by these symptoms. Novice doctors or novice TCM practitioners can use the Bayesian Network, which is realized in a computer

application, to help determine the type of heart syndrome quickly and precisely. The study results showed that expert knowledge in the form of weights could be used as a knowledge base in determining the type of syndrome in the heart organ. The calculation simulation results show that by using Bayesian Networks and the data from several patients in the form of symptoms that appear, it can be determined by the type of heart syndrome from these patients precisely according to conventional diagnoses from doctors. Details can be seen in Table 4, which shows the results of the simulation calculation.

The weakness of using the Bayesian Network for determining the type of heart syndrome is if the expert's preference weights are incorrect. For example, using the preference weights of someone who is not an expert in determining the type of heart syndrome, then the results will not be under reality. So in the selection of TCM, experts must have a lot of experience in dealing with patients and correct in establishing the diagnosis of the determination of the type of heart syndrome in patients.

The next research is to determine a disease syndrome of patients by combining all types of organ syndromes that exist in TCM, such as liver, gallbladder, heart, small intestine, lung, large intestine, spleen, and stomach. It is necessary to identify the symptoms that appear in each of these organ syndromes and determine which TCM experts can use their preferences as weights to build Bayesian Networks.

V. CONCLUSION

The use of syndrome diagnosis by the Bayesian Network method can describe the relationship between symptoms experienced by patients with the possible types of heart syndromes. The Bayesian Network structure makes the symptoms of the syndrome as variables that form a causal relationship based on calculating the probability of the type of heart syndromes. The results showed that the Bayesian Network could be used to determine the type of heart syndrome very well. The trials on seven patients produce the same diagnosis as the doctor's diagnosis and the Bayesian Network calculation.

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